

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
1 March 2001 (01.03.2001)

PCT

(10) International Publication Number
WO 01/14649 A1

(51) International Patent Classification⁷:
3/88, 5/28

E02F 3/92,

(74) Agent: KENNEDYS PATENT AGENCY LIMITED:
Floor 4, Queens House, 19-29 St Vincent Place, Glasgow
G1 2DT (GB).

(21) International Application Number: PCT/GB00/03208

(22) International Filing Date: 21 August 2000 (21.08.2000)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
9919801.2 21 August 1999 (21.08.1999) GB

(71) Applicant (for all designated States except US): PSL
TECHNOLOGY LIMITED [GB/GB]; Badentoy Ave-
nue, Portlethen, Aberdeen AB12 4YB (GB).

(71) Applicant and

(72) Inventor: LANE, Richard [ZA/ZA]; 116 Chelsea Lane,
Chelsea, Port Elizabeth (ZA).

(72) Inventor; and

(75) Inventor/Applicant (for US only): BROWN, Phil
[GB/GB]; Badentoy Avenue, Portlethen, Aberdeen AB12
4YB (GB).

(81) Designated States (national): AE, AG, AL, AM, AT, AT
(utility model), AU, AZ, BA, BB, BG, BR, BY, BZ, CA,
CH, CN, CR, CU, CZ, CZ (utility model), DE, DE (utility
model), DK, DK (utility model), DM, DZ, EE, EE (utility
model), ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL,
IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU,
LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL,
PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ,
UA, UG, US, UZ, VN, YU, ZA, ZW.

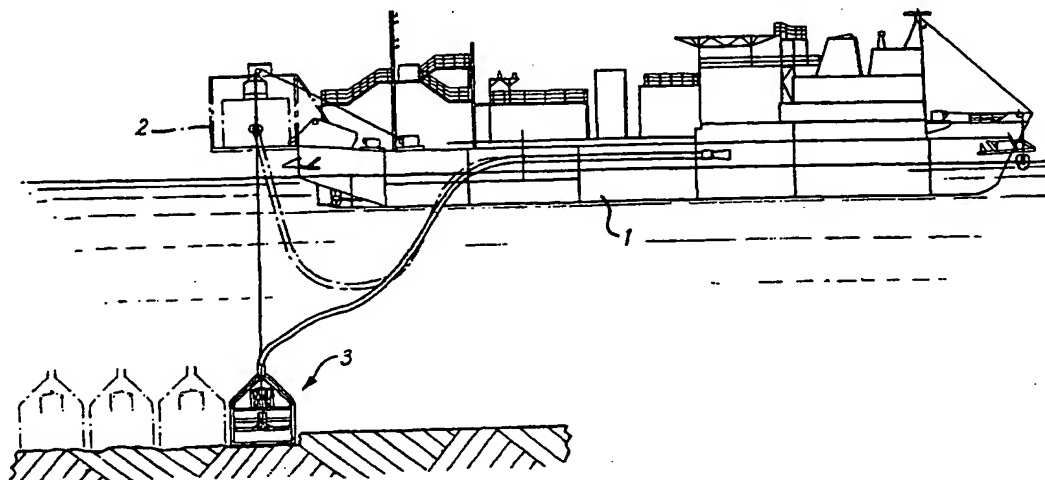
(84) Designated States (regional): ARIPO patent (GH, GM,
KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian
patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European
patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE,
IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG,
CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published:

— With international search report.

For two-letter codes and other abbreviations, refer to the "Guid-
ance Notes on Codes and Abbreviations" appearing at the begin-
ning of each regular issue of the PCT Gazette.

(54) Title: APPARATUS AND METHOD FOR SEA BED EXCAVATION



(57) Abstract: A sea-going vessel (1) provided with hoisting equipment (2) is employed for the controlled lowering and raising of excavation apparatus (3). The excavation apparatus (3) comprises a chamber (4) within which is contained agitation and suction means. The agitation means may comprise a propeller (9) employed to produce a high speed jet of sea water directed at the sea bed. Both agitation and suction means are controlled by communication means with the vessel (1). A method is described whereby an area of the sea bed is isolated by deployment of the chamber (4). Thereafter the sediment is disturbed by the agitation means before said disturbed sediment is conveyed to the vessel (1), for processing, by the suction means.

WO 01/14649 A1

1 Apparatus and Method for Sea Bed Excavation

2

3 The present invention relates to improved method and
4 apparatus for enabling the extraction of sediment and
5 other particulate materials from the sea bed.

6

7 In this specification, references to the sea bed should
8 be construed broadly, and as such should be deemed to
9 include river beds, lake beds and the like.

10

11 There are various applications, motivated by both
12 environmental and commercial considerations where it may
13 be beneficial to excavate an underwater sea bed. For
14 example, diamonds occur in certain rock and sediment
15 formations lying below the surface of the sea bed. This
16 is the case on the southern west coast of Africa, where
17 typically the highest concentrations of diamond deposits
18 lie between approximately 0.3 metres and 0.8 metres below
19 the gravel layer surface. Apparatus is required for
20 extracting the top layer, preferably to a depth of
21 approximately one metre, to allow the diamonds to be
22 mined.

23

1 Another application lies in the dredging of harbours or
2 ports where the constant use of oil-based fuels to power
3 marine craft leads to the polluting of the sea bed;
4 creating the desire to provide a means for the periodic
5 lifting and filtering or other cleaning of the sea bed
6 material. A yet further application that is envisaged in
7 consequence to growing environmental concerns relates to
8 the extraction of drill cuttings in the vicinity of off-
9 shore drilling sites.

10
11 The present invention is not limited to these
12 applications but finds utility in any situation where it
13 might be advantageous to excavate the sea bed. Usually,
14 this will also involve the raising of the sea bed
15 particles or other matter to the surface where would be
16 positioned a ship or boat housing the means for
17 performing some operation such as cleaning or separating
18 the matter, for example.

19
20 In the art there are provided diverse means for
21 excavating sea beds. One such means that is used in
22 fairly loosely compacted sea beds involves the use of one
23 or more suction units that are dragged by an overhead
24 ship across the sea floor. Suction is provided by
25 pumping apparatus located on the ship. However this
26 technique is associated with a number of disadvantages,
27 including the relative low efficiency of employing
28 suction as a sole means to encourage the dislodging and
29 uplifting of sea bed material. Movement of the suction
30 means in loosely defined linear paths also leads to poor
31 surface coverage of the entire sea bed; there inevitably
32 being gaps between the linear paths and inconsistencies
33 in the depth of penetration of the apparatus. Dragging
34 heavy equipment across the sea bed may also lead to the

WO 01/14649

1. inadvertent damage of pipelines or other sub sea
2. structures.

3
4 It is an object of the present invention therefore to
5 provide an improvement to this technique, and moreover to
6 offer a systematic method for removing the sediment top
7 layer of a sea bed with improved sea bed coverage at a
8 consistent depth.

9
10 According to the present invention there is provided
11 apparatus for use on a sea bed, the apparatus comprising
12 a chamber defining a volume of sea water located above an
13 area to be excavated, wherein the apparatus further
14 comprises agitation means located within the chamber for
15 agitating the sea bed in the said area and one or more
16 suction means for receiving sediment or other sea bed
17 material agitated by said agitation means.

18
19 Preferably the chamber is substantially open at a lower
20 part thereof.

21
22 Alternatively the chamber is partially closed at a lower
23 part thereof by a flexible membrane and securing means,
24 wherein the flexible membrane defines an enclosed
25 passageway between the chamber and the sea bed.

26
27 The suction means may communicate with one or more rigid
28 or flexible delivery risers for conveying the sea bed
29 material to a vessel or platform located on the sea
30 surface. Typically the vessel or platform would be
31 provided with pumping equipment for generating suction in
32 the suction means.

33

1 The chamber preferably acts as a barrier to contain the
2 agitated material from the sea bed within a volume
3 defined by the chamber. This serves to increase the
4 efficiency of the apparatus in that the disturbed sea bed
5 material is captured in the excavation area such that it
6 is maintained as available for collection by the suction
7 means.

8
9 The agitation means is preferably a device for jetting
10 sea water at the sea bed. It may for example comprise of
11 a hydraulically driven propeller that is adapted to
12 propel sea water within the chamber forcibly toward the
13 sea bed. The propeller would encourage a circular flow
14 of water in a horizontal plane, but other means may also
15 be included, such as vanes, fins, to encourage such
16 circular flow.

17
18 Alternatively, the agitation means comprises mechanical
19 blades or other members adapted to agitate the sea bed by
20 consequence of physically impacting the sea bed. A yet
21 further alternative may be that the agitation means
22 incorporates a sonic or ultrasonic device.

23
24 Preferably the suction means includes one or more inlets
25 for the intake of sea bed material, wherein the or each
26 inlet is disposed toward the perimeter of the chamber.
27 Most preferably, an inlet is provided at each corner of
28 the lower open side of the chamber.

29
30 The chamber may be further provided with a vent to
31 balance the volume of water in the chamber. The vent may
32 be associated with a valve or plug such that the vent is
33 kept open in normal operation, but in the event that the
34 apparatus becomes trapped in the sea bed can be closed

1 enabling the suction process to be reversed thus freeing
2 the apparatus. Reversal of the suction process may
3 involve the use of the agitation means.

4
5 Preferably, the chamber has a skirt at the lower edge of
6 its side walls, the skirt being robust and resilient.

7
8 According to a second aspect of the invention there is
9 provided a method of excavating a sea bed comprising the
10 steps of isolating an area of the sea bed; agitating the
11 sea bed in the said area and sucking the agitated sea bed
12 material to a surface vessel or the like.

13
14 Preferably the area is isolated by a physical barrier.
15 The sea bed may be agitated by inducing high velocity
16 fluid movement inside the isolated area.

17
18 Preferably the said method is conducted for a first
19 period of time and then repeated for successive periods
20 in respect of successive areas to be excavated.

21
22 Most preferably each successive excavation area is
23 adjacent the preceding area such that optimum coverage of
24 the sea bed is performed.

25
26 In order to better convey the invention embodiments will
27 now be described by way of example only with reference to
28 the accompanying Figures, in which:

29
30 Fig.1 shows a schematic elevation of a subsea
31 diamond mining system;

32
33 Fig. 2 shows in elevation excavation apparatus in
34 accordance with the invention;

Fig. 3 is a plan view of the excavation apparatus illustrated in Fig. 2;

Fig. 4 is a computer generated simulation of the movement of sea water and sea bed material inside the chamber of Figs. 2 and 3;

Fig. 5 is a plan view of an alternative embodiment of the excavation apparatus illustrated in Fig. 2; and

Fig. 6 shows in elevation an alternative embodiment of the excavation apparatus in accordance with the invention;

With reference firstly to Fig. 1, a sea going vessel 1 is provided with hoisting equipment 2 for the controlled lowering and raising of excavation apparatus, generally depicted at 3. The vessel may be provided with means for separating diamonds or material including diamonds from other waste material obtained from the sea bed. It should be appreciated that such means are not critical to the present invention; the invention hereto being concerned with the efficient and systematic collection of excavated material from the sea bed.

The excavation apparatus 3 is more clearly depicted in Figs. 2 and 3. The apparatus 3 includes a chamber 4 formed substantially as a cube, but with an open lower side. The lower side 5 is therefore approximately square, and in the example embodiment is dimensioned with sides of 5 metres.

1 A twenty inch diameter lift line 6 feeds into the chamber
2 and divides via a manifold into four arms 7, each arm 7
3 terminating with an inlet 8. The line 6 provides a
4 suction medium for sucking and conveying sea bed material
5 up to the vessel 1.

6
7 Descending through the centre of the chamber is a
8 relatively powerful water driven propeller 9. The
9 propeller 9 is adapted to thrust sea water downwardly and
10 forcibly onto the sea bed. The momentum of the propelled
11 sea water is sufficient to agitate the sea bed to such
12 extent as to cause sediment and other particles to
13 unsettle and travel around the chamber 4. It will be
14 appreciated that the rotary action of the propeller 9
15 will cause the sea water and agitated sea bed material to
16 move in a swirling direction, which will encourage the
17 sea bed material to migrate to the corners of the chamber
18 4. Accordingly, the suction inlets 8 are ideally located
19 at these corners for the efficient collection of the sea
20 bed material.

21
22 This may be more clearly demonstrated by Fig. 4 which
23 illustrates a simulation of the movement of the seabed
24 material in the chamber 4. The velocity of the material
25 is dependent on its location in relation to both the
26 propeller 9 and the suction inlets 8. Accordingly,
27 material located directly under the propeller 9 and
28 towards the centre of the sides of the chamber 4 is
29 affected least, while the material located towards the
30 edges of the propeller 9 and adjacent to the suction
31 inlets 8 is displaced most.

32

33 In an alternative embodiment, the chamber 4 may be
34 provided with means to improve the swirling effect of the

1 propeller 9 to ensure that the seabed within the area of
2 the chamber 4 is efficiently agitated. Figure 5
3 illustrates such an alternative embodiment where baffles
4 or directing blades 10 positioned below the propeller 9
5 are used to achieve this effect.

6
7 A further embodiment of the chamber 4 may be provided
8 such that a flexible membrane 11 and chain 12 are
9 incorporated on the lower side 5 of the chamber. Such an
10 embodiment is illustrated in Figure 6. The flexible
11 membrane 11 is employed to define a shallow passageway 13
12 across the sea bed. The propeller 9 is then used to
13 generate a high velocity water flow across the sea bed.
14 The water flow enters the passageway 13 at the inlet 14
15 before passing into the suction inlet 8 at the other end.
16 As the water flow passes through the passageway 13 it
17 carries with it sediment so permitting excavation of the
18 sea bed. The chain 12 is employed to weigh down the
19 flexible membrane 11 and so stop it billowing upwards
20 when the high velocity water flow passes underneath.

21
22 As the sea going vessel 1 passes over the area to be
23 excavated, the apparatus 3 is placed such that the
24 chamber 4 is stationary on the seabed. The sediment is
25 then agitated by the action of the propeller 9. The
26 suction arms 7 draw the sediment through the inlets 8 to
27 the vessel 1. Agitation of a single area is typically
28 done for 30-45 seconds depending on the nature of the sea
29 bed to allow an appropriate depth to be excavated.

30

31 Once in the vessel 1 the sediment can be filtered to
32 remove the desired material, such as diamonds, and
33 subsequently returned to the sea bed. The apparatus is
34 then translocated to a neighbouring section of the sea

1 bed and the process is repeated. The design of the
2 apparatus is such that the entire sea bed can be covered
3 improving the overall efficiency of the process.

4
5 Although unlikely, it might be possible as a result of
6 the agitation process that the apparatus can sink into
7 the sea bed and can become stuck. Accordingly, the
8 chamber 4 is also provided with a valve (not shown) which
9 is open during normal operation. However, in the event
10 that the apparatus becomes stuck in the sea bed the valve
11 can be closed and the suction process reversed to free
12 the apparatus. Potentially, this may be achieved in two
13 ways, namely: 1) the suction through the lift line 6 may
14 be replaced by downward flow, or 2) the suction through
15 the lift line may be deactivated and the upward reaction
16 force of the propeller 9 be relied upon.

17
18 It will be noted from the example embodiments that the
19 agitation of the sea bed is achieved without causing any
20 direct impacting of the agitation device on the sea bed.
21 This mitigates the possibility of damaging any existing
22 structures that might pre-exist on the sea floor.

23
24 A further advantage of the present invention is that
25 there is provided apparatus with improved
26 capacity/efficiency for excavating a sea bed or the like
27 as a result of improved coverage, higher concentration of
28 material entering the suction arms and deeper penetration
29 of the bed.

30
31 Further modifications and improvements may be added
32 without departing from the scope of the invention herein
33 intended.

1 CLAIMS

2

3 1) Apparatus for use on the sea bed comprising a chamber
4 defining a volume of sea water located above an area
5 to be excavated, wherein the apparatus further
6 comprises agitation means located within the chamber
7 for agitating the sea bed in the said area and one or
8 more suction means for receiving sediment or other
9 sea bed material agitated by said agitation means.

10

11 2) Apparatus for use on the sea bed as claimed in Claim
12 1 wherein the chamber is substantially open at the
13 lower end thereof.

14

15 3) Apparatus for use on the sea bed as claimed in Claim
16 1 wherein the chamber is partially closed at the
17 lower end thereof by a flexible membrane and securing
18 means, wherein the flexible membrane defines an
19 enclosed passageway between the chamber and the sea
20 bed.

21

22 4) Apparatus for use on the sea bed as claimed in any of
23 the preceding claims wherein the suction means may
24 communicate with one or more rigid or flexible
25 delivery risers for conveying the sea bed material to
26 a vessel or platform located on the sea surface.

27

28 5) Apparatus for use on the sea bed as claimed in any of
29 the preceding claims wherein the vessel or platform
30 would be provided with pumping equipment for
31 generating suction in the suction means.

32

33 6) Apparatus for use on the sea bed as claimed in any of
34 the preceding claims wherein the chamber acts as a

1 barrier to contain the agitated material from the sea
2 bed within a volume defined by the chamber so
3 increasing the efficiency of the apparatus.

4

5 7) Apparatus for use on the sea bed as claimed in any of
6 the preceding claims wherein the agitation means is a
7 device for jetting sea water at the sea bed.

8

9 8) Apparatus for use on the sea bed as claimed in Claim
10 7 wherein the agitation means is a hydraulically
11 driven propeller.

12

13 9) Apparatus for use on the sea bed as claimed in Claim
14 7 and 8 wherein the agitation means employs means for
15 directing the jetting sea water.

16

17 10) Apparatus for use on the sea bed as claimed in Claim
18 9 wherein the means for directing the jetting sea
19 water are one or more vanes.

20

21 11) Apparatus for use on the sea bed as claimed in Claim
22 9 wherein the means for directing the jetting sea
23 water are one or more fins.

24

25 12) Apparatus for use on the sea bed as claimed in Claims
26 1 to 6 wherein the agitation means comprises
27 mechanical blades or other members adapted to agitate
28 the sea bed by consequence of physically impacting
29 the sea bed.

30

31 13) Apparatus for use on the sea bed as claimed in Claims
32 1 to 6 wherein the agitation means is a sonic or
33 ultrasonic device.

34

1 14) Apparatus for use on the sea bed as claimed in any of
2 the preceding claims wherein the suction means
3 includes one or more inlets for the intake of sea bed
4 material.

5

6 15) Apparatus for use on the sea bed as claimed in any of
7 the preceding claims wherein the or each inlet is
8 disposed toward the perimeter of the chamber.

9

10 16) Apparatus for use on the sea bed as claimed in any of
11 the preceding claims wherein the chamber comprises a
12 vent to balance the volume of water in the chamber.

13

14 17) Apparatus for use on the sea bed as claimed in any of
15 the preceding claims wherein the vent is associated
16 with a valve or plug such that the vent is kept open
17 in normal operation, but in the event that the
18 apparatus becomes trapped in the sea bed can be
19 closed enabling the suction process to be reversed
20 thus freeing the apparatus.

21

22 18) Apparatus for use on the sea bed as claimed in any of
23 the preceding claims wherein the reversal of the
24 suction process involves the use of the agitation
25 means.

26

27 19) Apparatus for use on the sea bed as claimed in any of
28 the preceding claims wherein the chamber has a skirt
29 at the lower edge of its side walls, the skirt being
30 robust and resilient.

31

32 20) A method of excavating a sea bed comprising the steps
33 of:

34 1. Isolating an area of the sea bed;

- 1 2. Agitating the sea bed in the said area;
2 3. Sucking the agitated sea bed material to a surface
3 vessel or the like.

4

- 5 21) A method of excavating a sea bed as claimed in Claim
6 20 whereby the area is isolated by a physical
7 barrier.

8

- 9 22) A method of excavating a sea bed as claimed in Claim
10 20 and 21 whereby the sea bed is agitated by inducing
11 high-velocity fluid movement inside the isolated
12 area.

13

- 14 23) A method of excavating a sea bed as claimed in Claims
15 20 to 22 whereby the said method is conducted for a
16 first period of time and then repeated for successive
17 periods in respect of successive areas to be
18 excavated.

19

- 20 24) A method of excavating a sea bed as claimed in Claim
21 23 whereby each successive excavation area is
22 adjacent to the preceding area such that optimum
23 coverage of the sea bed is performed.

INTERNATIONAL SEARCH REPORT

International Application No.
PCT/GB 00/03208

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	PATENT ABSTRACTS OF JAPAN vol. 016, no. 428 (M-1307), 8 September 1992 (1992-09-08) & JP 04 146333 A (UBE IND LTD), 20 May 1992 (1992-05-20) abstract figures 1-3,7 ---	1,2,4-6, 14, 19-21, 23,24
X	DE 39 23 113 A (TELEFUNKEN SYSTEMTECHNIK) 24 January 1991 (1991-01-24) ---	1,2,4,6, 7,14,20, 21
A	figures column 1, line 45 -column 2, line 14 column 2, line 28 - line 51 ---	5,9, 22-24
X	DE 32 45 821 A (HAMBURGER IND DIENSTLEISTUNGSG) 14 June 1984 (1984-06-14) abstract: figures 1-3 page 13 -page 14 ---	1,3,4,6, 14,19-21
A	abstract: figures 1-3 page 13 -page 14 ---	5
A	EP 0 047 803 A (DOSBOUW) 24 March 1982 (1982-03-24) figures ---	1,3
P,A	DE 199 14 703 A (GOUDSCHELP CONSERVENFAB BV) 21 October 1999 (1999-10-21) figures ---	1,20
A	EP 0 134 312 A (DOSBOUW V O F) 20 March 1985 (1985-03-20) figures ---	1,7-12
A	US 4 127 950 A (TILLINGHAST WILLIAM S ET AL) 5 December 1978 (1978-12-05) figures -----	1,20

INTERNATIONAL SEARCH REPORT

International application No.
PCT/GB 00/03208

A. CLASSIFICATION OF SUBJECT MATTER IPC 7 E02F3/92 E02F3/88 E02F5/28		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) IPC 7 E02F A01K		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practical, search terms used) EPO-Internal, PAJ		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 1 719 668 A (MC EACHERN) 2 July 1929 (1929-07-02)	1, 2, 4, 6, 7, 14, 20, 21
A	page 1, line 1 - line 17 page 1, line 38 - line 88 figures	9, 22-24
X	PATENT ABSTRACTS OF JAPAN vol. 1996, no. 07, 31 July 1996 (1996-07-31) & JP 08 060695 A (MITSUBISHI HEAVY IND LTD), 5 March 1996 (1996-03-05) abstract	1, 2, 20, 21
A	figures 1.2	6-12, 22
-/-		
<div style="display: flex; justify-content: space-between;"> <input checked="" type="checkbox"/> Further documents are listed in the continuation of box C. <input checked="" type="checkbox"/> Patent family members are listed in annex. </div>		
<div style="display: flex;"> <div style="flex: 1;"> <p>* Special categories of cited documents:</p> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier document but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> </div> <div style="flex: 1;"> <p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone</p> <p>"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.</p> <p>"Z" document member of the same patent family</p> </div> </div>		
Date of the actual completion of the international search	Date of mailing of the international search report	
31 October 2000	08/11/2000	
Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016		Authorized officer Guthmuller, J

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/GB 00/03208

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
US 1719668	A.	02-07-1929	NONE	
JP 08060695	A	05-03-1996	NONE	
JP 04146333	A	20-05-1992	NONE	
DE 3923113	A	24-01-1991	NONE	
DE 3245821	A	14-06-1984	NONE	
EP 0047803	A	24-03-1982	NONE	
DE 19914703	A	21-10-1999	NL 1008794 C BE 1011978 A GB 2335935 A	05-10-1999 07-03-2000 06-10-1999
EP 0134312	A	20-03-1985	NONE	
US 4127950	A	05-12-1978	NONE	

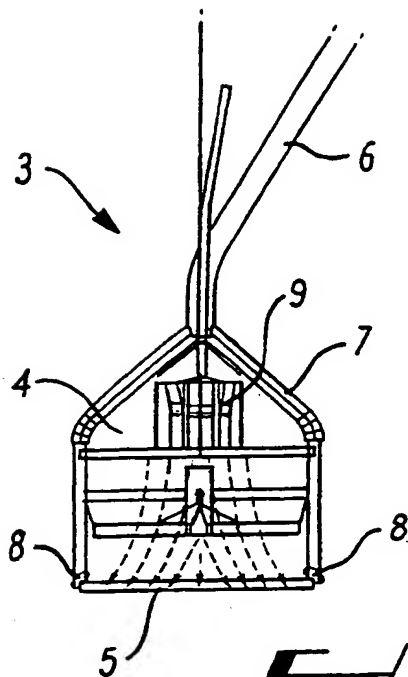


Fig. 2

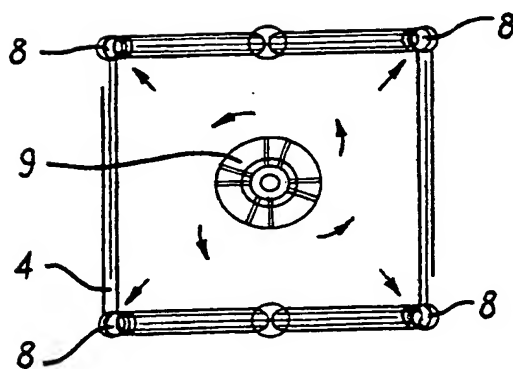


Fig. 3

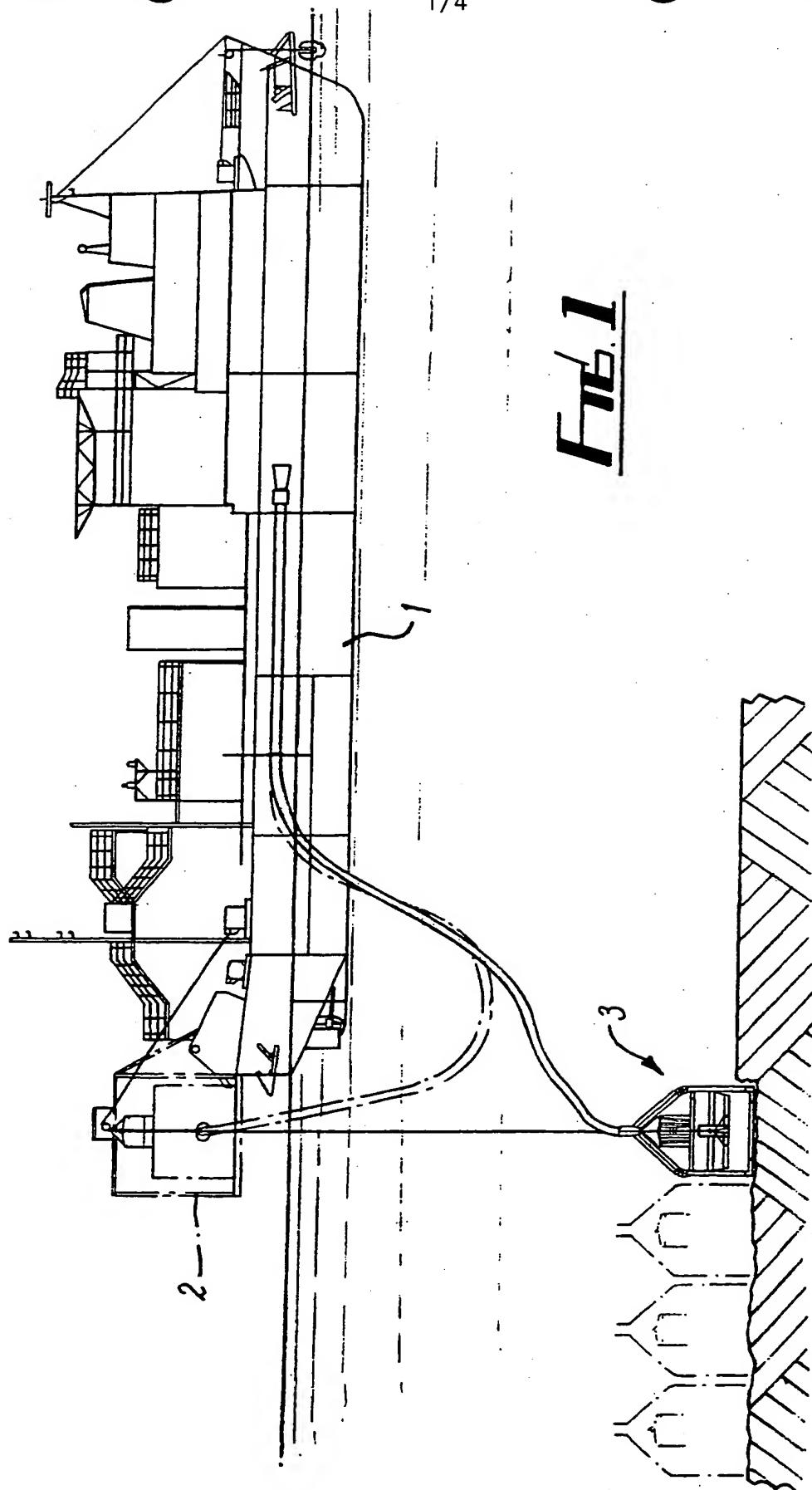
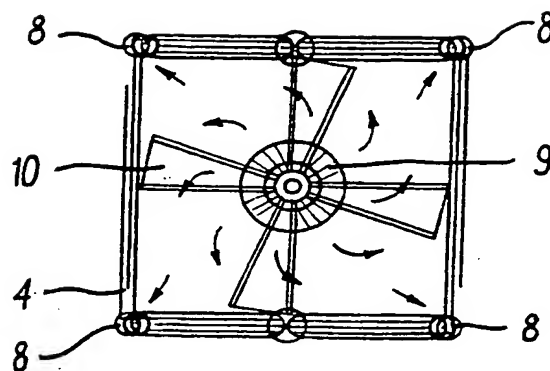
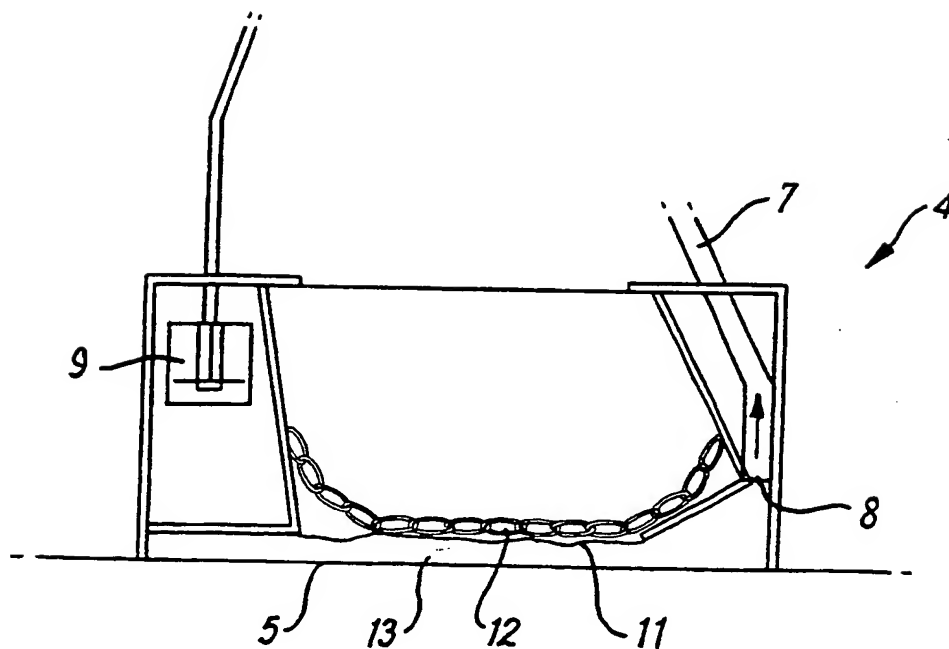


Fig. 1

SUBSTITUTE SHEET (RULE 26)

**FIG. 5****FIG. 6**

SUBSTITUTE SHEET (RULE 26)

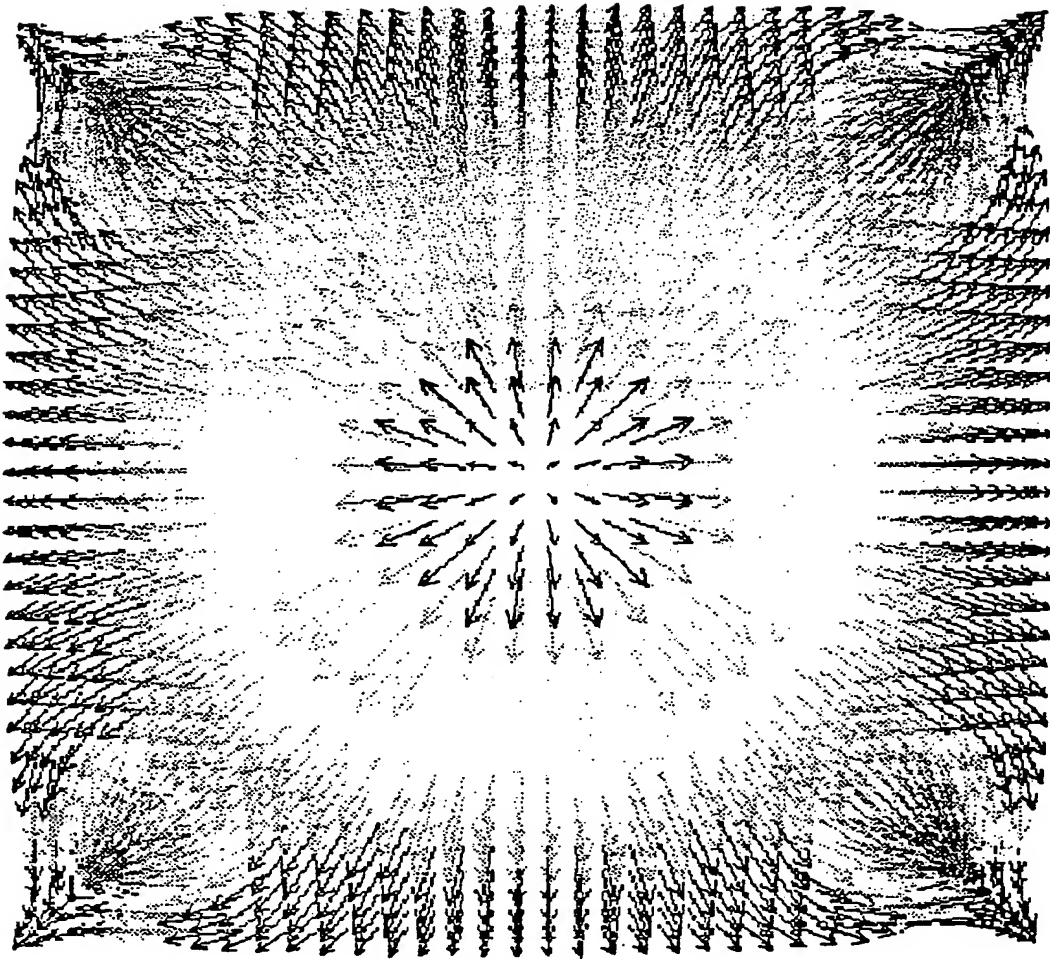


FIG. 4

BEST AVAILABLE COPY

SUBSTITUTE SHEET (RULE 26)